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(54) Acoustic passive radiator with rocking-mode reduction

Akustischer Passivstrahler mit Reduzierung von Schaukelbewegungen

Radiateur passif acoustique avec réduction des modes de basculement

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EP 1 555 849 B1

Description

BACKGROUND

[0001] The invention relates to acoustic passive radiators, and more particularly to reducing rocking mode vibration.

[0002] Concerning prior art, the document D2=US3780824 can be cited, which discloses an acoustic passive radiator, comprising a diaphragm for radiating acoustic energy; a surround for pneumatically sealing said diaphragm and an acoustic enclosure; and a plurality of suspension elements for physically coupling said diaphragm and said acoustic enclosure, wherein said the suspension elements and said surround coact to control the motion of said diaphragm and to support the weight of said diaphragm.

[0003] It is an important object of the invention to provide an acoustic passive radiator with reduced rocking mode vibration.

SUMMARY

[0004] According to the invention, an acoustic passive radiator includes a diaphragm for radiating acoustic energy; a surround for pneumatically sealing the diaphragm to an acoustic enclosure; and a plurality of discrete, non-surround, non-spider suspension elements for physically coupling the diaphragm and the acoustic enclosure. The non-surround suspension elements and the surround coact to control the motion of the diaphragm and to support the weight of the diaphragm.

[0005] Further aspects of the invention are set out in the accompanying dependent claims.

[0006] Other features, objects, and advantages will become apparent from the following detailed description, when read in connection with the accompanying drawing in which:

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

[0007]

FIGS. 1A and 1B are diagrammatic isometric views of a passive radiator diaphragm for illustrating some terms used in the specification ;

FIGS. 2A and 2B are views of an acoustic enclosure, a surround type suspension, and a passive radiator diaphragm for illustrating terms used in the specification;

FIGS. 3A - 3E are views of an enclosure element, a passive radiator diaphragm, and a passive radiator suspension assembly according to one aspect of the invention;

FIGS. 4A - 4C are views of alternative implementations of passive radiator diaphragms, illustrating features that can be combined with the inventive features as defined by the accompanying claim 1.

FIG. 5 is a view of an alternative implementation of a passive radiator, illustrating features that can be combined with the inventive features as defined by the accompanying claim 1.

FIG. 6 is a view of another alternative implementation of a passive radiator illustrating features that can be combined with the inventive features as defined by the accompanying claim 1.

FIG. 7 is a view of a further implemation of a passive radiator diaphragm and surround assembly illustrating features that can be combined with the inventive features as defined by the accompanying claim 1; and

FIG. 8 is a view of an alternate implementation of the passive radiator diaphragm and surround assembly of FIG.7 illustrating features that can be combined with the inventive features as defined by the accompanying claim 1.

DETAILED DESCRIPTION

[0008] With reference now to the drawings and more particularly to FIGS. 1A and 1B, there are shown views of a passive acoustic radiator diaphragm for illustrating some terms used in the specification. A passive acoustic radiator (sometimes referred to as a "drone") typically includes a diaphragm 10 that is mounted in an acoustic enclosure (not shown) by a suspension system (not shown). An acoustic driver radiates acoustic energy into the acoustic enclosure, causing pressure variations in the enclosure. The passive radiator diaphragm 10 vibrates, responsive to the pressure variations in the enclosure. In one common form of passive radiator, the diaphragm and the suspension are designed so that the diaphragm moves pistonically. In pistonic motion, all points on the diaphragm move uniformly along an intended axis of motion, as indicated by velocity vectors 42, and the points of the diaphragm do not move relative to each other. However, in some circumstances (such as the presence of lateral forces, uneven pressure or acoustic loading across the radiating surface, or suspension nonlinearities) points on the radiating surface may move nonuniformly along the intended axis of motion, so that points of the diaphragm move relative to each other and indicated by velocity vectors 43 which results in vibratory rotational motion as indicated by arrows 44 about an axis 46. Non-pistonic motion of the type shown in FIG. 1B is sometimes referred to as "rocking mode" vibration and the axis 46 is referred to as the rocking axis. Rocking mode vibration has undesirable acoustic effects, such as loss of acoustic efficiency or distortion of the sound radiated by the passive radiator. Rocking mode vibration tends to occur at specific frequencies that are related to characteristics of the diaphragm, the suspension, and the acoustic enclosure, the placement and the mechanical and acoustic characteristics of the acoustic driver, and other factors. Some practices or devices that can alleviate rocking mode vibration, for example multiple surrounds, "spiders," and other suspension elements, and symmetric placement of acoustic drivers relative to passive radiators, are difficult to implement in some types of loudspeaker units, such as compact low frequency woofer or subwoofer loudspeaker units.

[0009] The type of rocking mode vibration described above is the most commonly observed form of rocking mode. The devices and techniques disclosed herein generally act to prevent or control other, more complex, forms of rocking mode. For simplicity of explanation, the devices and techniques will be described relative to the type of rocking, mode described above.

[0010] The discussion above also relates to motion of a rigid diaphragm. Other modes, many of which have undesirable acoustic effects, may occur if the diaphragm is not rigid. "Buckling modes" and "potato chip" modes are examples of modes of non-rigid diaphragms that have undesirable acoustic effects. The devices and techniques disclosed herein may act to prevent or control undesirable non-rigid modes. For simplicity of explanation, the devices and techniques will be described as they relate to rocking mode vibration of a rigid diaphragm.

[0011] Referring now to FIG. 2A, there is shown a cross-sectional view of a portion of an acoustic enclosure, a surround type suspension, and a passive radiator diaphragm 10 for illustrating terms used in the specification. For convenience, the passive radiator diaphragm is shown as a planar element, but can take many forms, such as a cone shaped structure, or a structure with one or more non-planar surfaces. A suspension system that includes a surround 12 mechanically couples a passive radiator diaphragm 10 to an acoustic enclosure element 14 or some other structure. The diaphragm is typically mounted in an opening in acoustic enclosure element 14. The surround is designed so that the passive radiator diaphragm can vibrate in a direction indicated by arrow 16, and so that motion in directions transverse to direction 16, such as indicated by arrow 18 is inhibited. In addition to controlling the motion of the passive radiator diaphragm 10, the suspension supports the weight of the passive radiator diaphragm 10 and seals the passive radiator diaphragm and the enclosure element so that air cannot leak from one side of the enclosure element and diaphragm to the other through the opening in the enclosure element 14. To facilitate attaching the surround to the acoustic enclosure element 14, the surround may have an outer attachment area 20, and the enclosure element may have a frame structure (not shown). The surround may have a passive radiator attachment area 22 to facilitate attaching the surround to the passive radiator diaphragm 10. The surround has a roll area 24 that is formed into a geometry that facilitates motion in direction 16. A so called "double roll" configuration is shown, but several other configurations, such as single roll, corrugations, opposed rolls, and the like may be used.

[0012] FIG. 2B is a top plan view of the assembly of FIG. 2A, with the edge 26 of the enclosure element 14 and the edge 28 of the passive radiator diaphragm 10 indicated in dashed lines. Additionally, reference lines indicate correspondence between various points of the surround 12 in the two views. The surround is attached to the acoustic enclosure element 14 along outer attachment area 20 and to the passive radiator diaphragm 10 along passive radiator attachment area 22. Attachment is typically by an adhesive or some other fastening element or method. Ideally, the acoustic enclosure element and the passive radiator diaphragm are attached along attachment areas 20 and 22 in an air tight manner, so that air cannot leak from one side of the surround to the other. The "width" of the surround, as used herein, is the length w of unattached surround between the enclosure element 14 and the passive radiator diaphragm.

[0013] Referring to FIGS. 3A and 3B, there are shown a top plan view and a cross sectional view of an enclosure element 14 a passive radiator diaphragm 10, and a passive radiator suspension assembly according to one aspect of the invention. The suspension assembly includes a surround 12, similar to the surrounds of previous views. In addition to the surround 12, the suspension assembly includes two or more discrete non-surround suspension elements 32, for example flexures. The discrete suspension elements may be attached to the diaphragm at any convenient point (which may be in the attachment area 22, as shown). The suspension assembly performs the same functions (controlling direction of motion, supporting the weight of the diaphragm, and pneumatically sealing the acoustic enclosure element and the passive radiator diaphragm) as the suspensions of previous views. The surround provides the pneumatic sealing, while the weight supporting and the motion control are provided by the combination of the surround and the non-surround suspension elements.

[0014] Use of materials that have good stiffness, good internal damping, and that are thermally stable help to reduce or control rocking modes. In addition to good stiffness, good internal damping, and thermal stability, materials should have other qualities that are desirable for surround material, such as linearity and ease of bonding. For use in small enclosures, thermal stability is especially important. Solid polyurethanes, which have an elastic modulus in the range of 1.4×10^7 newtons/sq. meter, a tan delta of 0.1, good thermal stability, good linearity, and good bondability, are suitable.

[0015] In one embodiment of the configuration of FIGS. 3A and 3B, passive radiator diaphragm 10 is a planar aluminum disk with a diameter of about 12.5 inches (31.75 cm) and a thickness of about 0.5 inches (1.27 cm). The surround is a single roll surround of polyurethane foam 0.05 inches (1.27 mm) thick and 0.8 inches (2.03 cm) wide. The non-surround suspension elements include four bands of spring steel 0.006 inches (0.15 mm) thick 1.2 inches (3.05 cm) wide and 1.2 inches (3.05 cm) long.

[0016] FIG. 3C shows an alternate configuration of the device of FIGS. 3A and 3B. In the configuration of FIG. 3C, the diaphragm 10 has a so-called "racetrack" shape. In other configurations, the diaphragm may have other shapes, such as round or oval, and may take other forms, such as a cone shaped structure. FIG. 3C illustrates another feature of the invention that reduces or controls rocking mode vibration. The surround is wider (and may also be thicker) at locations that are prone to rocking mode vibration. For example, width w1may be greater than width w2.

[0017] FIGS. 3D and 3E show alternate arrangements of the surround 12 and the discrete non-surround suspension elements 32. The discrete non-surround suspension elements 32 and the surround may be mounted to the diaphragm 10 on the same side, as in FIG. 3A or on opposite sides, as shown in FIGS. 3D and 3E.

[0018] A passive radiator suspension according to FIGS. 3A - 3E is advantageous over conventional passive radiator suspensions because the non-surround suspension elements permits sharing of the weight support function between the surround and the non-surround suspension elements. This provides great design flexibility and allows the use of heavy diaphragms without requiring spiders or complex bulky surrounds that may limit the motion of the diaphragm or take up more space than desired, or both. The non-surround suspension elements can be placed at positions that are more likely than other positions to be prone to be subject to conditions that cause rocking mode vibration, for example at positions on the diaphragm that are subject to greater stress because of geometry, or where there are pressure differences across the diaphragm. The suspension system can be more easily designed so that a loudspeaker incorporating the invention can be oriented so that the intended direction of motion of the passive radiator is either horizontal (so that gravity is a force that is lateral to the direction of motion of the diaphragm) or vertical (so that gravity is a force that is parallel to the direction of motion of the diaphragm). Additionally, the passive radiator suspension may be made more resistant to drift or creep, so that it maintains its characteristics over time. Still further, the suspension may be made less susceptible to deformation of the surround due to pneumatic pressure.

[0019] Referring to FIG. 4A - 4C, there is shown cross-sectional and plan views of some alternative passive radiator diaphragm designs that control rocking mode vibration illustrating features that can be combined with the inventive features as defined by the accompanying claim 1. One method of controlling rocking mode vibration is to control mass distribution of the diaphragm. Generally, moving mass away from the axis of rotation for any rotational motion of the diaphragm increases the moment of inertia and causes rocking mode vibration to occur at lower frequencies. Moving mass toward the axis of rotation decreases the moment of inertia and causes rocking mode vibration to occur at higher frequencies. By distributing mass properly, it is possible to cause the rocking mode vibration frequencies to be below or above the operating frequency of the passive radiator. The lower rocking mode frequencies are typically of greater interest, because passive radiators are typically used to augment bass acoustic radiation, and the audio signals sent to loudspeakers employing passive radiators are often low-pass filtered to remove high frequency spectral components. In FIG. 4A, the diaphragm has the form of a frustoconical surface attached to a surround at the outer edge 54 of the diaphragm and an additional mass 48 attached to the inner edge 56 of the diaphragm, so that the mass is displaced from the rocking axis 46. One method for forming an implementation of FIG. 4A is to use a conventional acoustic driver cone and dust cover 58 for the diaphragm, attaching a tube 60, for example a coil former, or similar element, in a conventional way. Additionally, material may be placed inside the tube so that the additional mass includes the tube and the material that may have been deposited inside the tube. Other rocking mode limiting devices, such as a spider 50, may provide additional rocking mode control.

[0020] In the exemplary implementation of FIG. 4B illustrating features that can be combined with the inventive features as defined by the accompanying claim 1, the passive radiator diaphragm is thicker at the perimeter than at the center. The thickness may increase linearly (as shown by the solid line), may increase exponentially (as shown by the dashed line), or may increase in some regular or irregular manner determined experimentally or by computer simulation. FIG. 4C shows another passive radiator diaphragm in which the distribution of mass has been configured to increase (over a uniform thickness diaphragm) the moment of inertia to change a rocking mode frequency. The diaphragm of FIG. 4C has a cup shaped form, with a band or ring of material at the perimeter, increasing the mass at the perimeter. Additionally, the diaphragm may be attached to the surround at a point other than the lateral outer extremity of the diaphragm, so that the diaphragm is larger than the opening in which it is mounted. In one configuration the diaphragm has a lateral extension 33 so that the passive radiator diaphragm edge 28 lies outside the edge 26 of the enclosure element 14. The lateral extension 33 is offset from the enclosure opening so that the diaphragm does not strike the enclosure during operation. The passive radiator attachment area 22 lies inside the perimeter of the diaphragm. If the configuration permits, the passive radiator may be configured so that the ring or band of material and the lateral extension is outside the acoustic enclosure.

[0021] Referring now to FIG. 5, there is shown another alternative passive radiator diaphragm illustrating features that can be combined with the inventive features as defined by the accompanying claim 1. In the implementation of FIG. 5, the diaphragm 10 includes a skin element 34 and a mass element 36. The skin element 34 may be a unitary structure with the surround 12 as shown, or may be separate from the surround. If the diaphragm is not sufficiently stiff and exhibits membrane behavior, the mass element may include stiffening elements, such as ribs 52, for example.

[0022] An implementation according to FIG. 5 provides even greater flexibility of mass distribution. The mass element 36 may, for example, be a ring shaped structure as shown in FIG. 6, providing great concentration of mass at the perimeter and a significantly higher moment of inertia than conventional passive radiator diaphragms. The mass element 36 may also take the form of the diaphragms of FIGS. 4A - 4C, with the additional flexibility that the surface of the mass element 36 need not be unbroken or continuous.

[0023] Referring now to FIG. 6, there is shown another implementation illustrating features that can be combined with the inventive features as defined by the accompanying claim 1. In the implementation of FIG. 6, different sections of the diaphragm 10 or of the mass element 36 are formed of different material. For example, a first inner section 38 may be of a low density material, while an outer section 40 may be of higher density material. Examples of low density materials may include light papers or plastics, foams, or honeycomb structures that are unfilled or filled with low density material, while examples of higher density materials may include heavy papers or plastics, metal, wood, composites, or honeycomb structures filled with higher density material.

[0024] FIGS. 7 and 8 show variations of the implementation of FIGS. 5 and 6 illustrating features that can be combined with the inventive features as defined by the accompanying claim 1. As shown in FIG. 7, the skin element 34 may encase a sufficient portion (for example more than half of the surface area) so that passive radiator can be assembled without adhesive and so that the elements of the passive radiator remain in position, without adhesive, during operation. In other implementations, (as in FIG. 8) the skin element 34 may be completely enclose the mass element 36. In the variation shown in FIG. 7, the mass element is formed to increase the moment of inertia as described above. In the variation shown in FIG. 8, diaphragm has the form of FIG. 6. Since the diaphragm may be sealed, materials such as powders, granular material, liquids, materials that should not be exposed to the environment, and the like can be used for portions of the mass element.

[0025] A passive radiator according to FIGS. 7 and 8 can be formed by insert molding. The mass element may be placed in a cavity in a mold. The cavity can then be filled with a flowable, curable material so that it partially or completely encloses the mass element. The flowable, curable material may then be set or cured so that it is suitable form for, and so that is suitably elastomeric for, use as a passive radiator suspension. Suitable materials include thermosettable, thermoplastic, or curable materials such as closed-cell polyurethane foams. Insert molding permits more precise positioning of the mass element 36 relative to the skin element 34 than other manufacturing methods. Because the mass element and the skin element can be more precisely aligned, the passive radiator can be made less prone to rocking mode vibration resulting from misalignment of the passive radiator elements. Additionally, the passive radiator can be formed without the use of adhesives, which eliminates a source of mechanical failure and which eliminates manufacturing steps related to the depositing and curing of adhesives.

[0026] The implementations of FIGS. 3A - 8 may be combined. For example, a diaphragm assembly may include an unskinned honeycomb portion and a metal portion according to FIG. 6 and a skin element according to FIG. 5; the diaphragm may be thicker at the perimeter according to FIGS. 4B or 4C, or both, and have discrete non-surround suspension elements channels according to FIG. 3A. Many other combinations are possible.

[0027] The various configurations and geometries may be manufactured in a variety of ways. For example, the implementations of FIG. 4B can be manufactured by metal forming or casting, or may be manufactured by removing material from a slug or metal, plastic, or some other material. The implementation of FIG. 4C could be manufactured by metal forming or casting, or by removing material from or adding material to a slug of metal, plastic, or some other material.

[0028] It is evident that those skilled in the art may now make numerous uses of and departures from the specific apparatus and techniques disclosed herein without departing from the inventive concepts. Consequently, the invention is to be construed as embracing each and every novel feature and novel combination of features disclosed herein and limited only by the scope of the appended claims.

Claims

1. An acoustic passive radiator, comprising:

> a diaphragm (10) for radiating acoustic energy;
> a surround (12) for pneumatically sealing said diaphragm (10) to an acoustic enclosure (14); and
> a plurality of discrete, non-surround, non-spider suspension elements (32) for physically coupling said diaphragm (10) and said acoustic enclosure (14), wherein said non-surround suspension elements (32) and said surround (12) coact to control the motion of said diaphragm (10) and to support the weight of said diaphragm.

2. An acoustic passive radiator in accordance with claim 1, wherein each of said discrete suspension elements (32) comprises a metal band, each of said metal bands having one end constructed and arranged to be attached to said diaphragm (10) and another end constructed and arranged to be attached to said enclosure (14).

3. An acoustic passive radiator in accordance with claim 1 or claim 2, wherein said plurality of discrete suspension elements (32) and said surround (12) are constructed and arranged to be attached to said diaphragm (10) at a common point.

4. An acoustic passive radiator in accordance with claim 1, 2 or 3, wherein said plurality of discrete suspension elements (32) are mechanically attached to said diaphragm (10) at discrete points, and wherein said surround (12) is mechanically attached to said diaphragm (10) along a continuous surface, wherein said continuous surface includes said discrete points.

5. An acoustic passive radiator in accordance with any of claims 1 to 4, wherein said diaphragm (10) is constructed of metal.

6. An acoustic passive radiator in accordance with any of claims 1 to 5, wherein said acoustic enclosure (14) has a frame structure to facilitate attaching said surround to said acoustic enclosure (14).

7. An acoustic passive radiator in accordance with any of claims 1 to 6, wherein said surround (12) has a non-uniform width.

8. An acoustic passive radiator in accordance with claim 7 wherein:

said diaphragm (10) has a perimeter portion and a central portion, said perimeter portion being thicker than said central portion;
a skin element (34) encasing said diaphragm, said skin element comprising said surround (12) for physically coupling said passive radiator to said acoustic enclosure (14); and
said discrete suspension elements (32) comprise a non-pneumatically sealing, non-surround, non-spider suspension element.

Patentansprüche

1. Schall-Passivstrahler, der Folgendes umfasst:

eine Membran (10) zum Ausstrahlen von Schallenergie;
eine Einfassung (12) zum pneumatischen Dichten der genannten Membran (10) an einem Schallgehäuse (14); und
mehrere diskrete, nicht einfassende, nicht spinnenartige Aufhängungselemente (32) zum physischen Koppeln der genannten Membran (10) und des genannten Schallgehäuses (14), wobei die genannten nicht einfassenden Aufhängungselemente (32) und die genannte Einfassung (12) zusammenwirken, um die Bewegung der genannten Membran (10) einzuschränken und das Gewicht der genannten Membran zu tragen.

2. Schall-Passivstrahler nach Anspruch 1, wobei die genannten diskreten Aufhängungselemente (32) jeweils ein Metallband umfassen, wobei die genannten Metallbänder jeweils ein Ende aufweisen, das dazu ausgebildet und angeordnet ist, an der genannten Membran (10) befestigt zu werden und ein anderes Ende aufweisen, das dazu ausgebildet und angeordnet ist, an dem genannten Gehäuse (14) befestigt zu werden.

3. Schall-Passivstrahler nach Anspruch 1 oder Anspruch 2, wobei die genannten mehreren diskreten Aufhängungselemente (32) und die genannte Einfassung dazu ausgebildet und angeordnet sind, an einem gemeinsamen Punkt an der genannten Membran (10) befestigt zu werden.

4. Schall-Passivstrahler nach Anspruch 1, 2 oder 3, wobei die genannten mehreren diskreten Aufhängungselemente (32) an diskreten Punkten mechanisch an der genannten Membran (10) befestigt sind und wobei die genannte Einfassung (12) entlang einer kontinuierlichen Fläche mechanisch an der genannten Membran (10) befestigt ist, wobei die genannte kontinuierliche Fläche die genannten diskreten Punkte enthält.

5. Schall-Passivstrahler nach einem der Ansprüche 1 bis 4, wobei die genannte Membran (10) aus Metall gebildet ist.

6. Schall-Passivstrahler nach einem der Ansprüche 1 bis 5, wobei das genannte Schallgehäuse (14) eine Rahmenstruktur aufweist, um das Befestigen der genannten Einfassung an dem genannten Schallgehäuse (14) zu erleichtern.

7. Schall-Passivstrahler nach einem der Ansprüche 1 bis 6, wobei die genannte Einfassung (12) eine uneinheitliche Breite aufweist.

8. Schall-Passivstrahler nach Anspruch 7, wobei:

die genannte Membran (10) einen Umfangsabschnitt und einen Mittenabschnitt aufweist, wo-

bei der genannte Umfangsabschnitt dicker ist als der genannte Mittenabschnitt;
ein Hautelement (34) die genannte Membran einschließt, wobei das genannte Hautelement die genannte Einfassung (12) umfasst, um den genannten Passivstrahler an das genannte Schallgehäuse (14) zu koppeln; und
die genannten diskreten Aufhängungselemente (32) ein nicht pneumatisch dichtendes, nicht einfassendes, nicht spinnenartiges Aufhängungselement umfassen.

Revendications

1. Radiateur passif acoustique, comprenant :

une membrane (10) destinée à rayonner une énergie acoustique ;
une suspension surround (12) destinée à sceller pneumatiquement ladite membrane (10) sur une enceinte acoustique (14) ; et
une pluralité d'éléments discrets de suspension, non surround et non spider (32) destinée à coupler physiquement ladite membrane (10) et ladite enceinte acoustique (14), dans lequel lesdits éléments de suspension non surround (32) et ladite suspension surround (12) coagissent pour contrôler le mouvement de ladite membrane (10) et supporter le poids de ladite membrane.

2. Radiateur passif acoustique selon la revendication 1, dans lequel chacun desdits éléments discrets de suspension (32) comprend une bande métallique, chacune desdites bandes métalliques ayant une extrémité construite et agencée pour être attachée à ladite membrane (10) et une autre extrémité construite et agencée pour être attachée à ladite enceinte (14).

3. Radiateur passif acoustique selon la revendication 1 ou la revendication 2, dans lequel ladite pluralité d'éléments discrets de suspension (32) et ladite suspension surround (12) sont construites et agencées pour être attachées à ladite membrane (10) au niveau d'un point commun.

4. Radiateur passif acoustique selon la revendication 1, 2 ou 3, dans lequel ladite pluralité d'éléments discrets de suspension (32) est attachée mécaniquement à ladite membrane (10) au niveau de points discrets, et dans lequel ladite suspension surround (12) est attachée mécaniquement à ladite membrane (10) le long d'une surface continue, ladite surface continue comportant lesdits points discrets.

5. Radiateur passif acoustique selon l'une quelconque des revendications 1 à 4, dans lequel ladite membrane (10) est construite en métal.

6. Radiateur passif acoustique selon l'une quelconque des revendications 1 à 5, dans lequel ladite enceinte acoustique (14) a une structure de cadre pour faciliter la fixation de ladite suspension surround à ladite enceinte acoustique (14).

7. Radiateur passif acoustique selon l'une quelconque des revendications 1 à 6, dans lequel ladite suspension surround (12) a une largeur non uniforme.

8. Radiateur passif acoustique selon la revendication 7, dans lequel :

ladite membrane (10) a une partie périmétrale et une partie centrale, ladite partie périmétrale étant plus épaisse que ladite partie centrale ;
un élément de peau (34) enfermant ladite membrane comprenant ladite suspension surround (12), ledit élément de peau servant à coupler physiquement ledit radiateur passif à ladite enceinte acoustique (14) ; et
lesdits éléments de suspension discrets (32) comprennent un élément de suspension non surround, non spider, non scellant pneumatiquement.

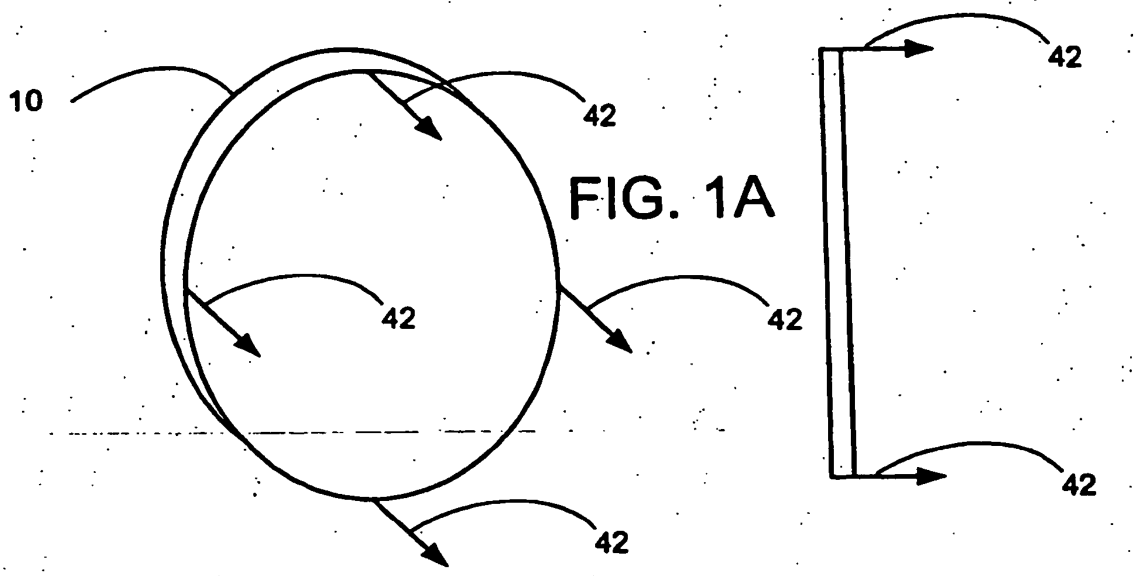

FIG. 1A

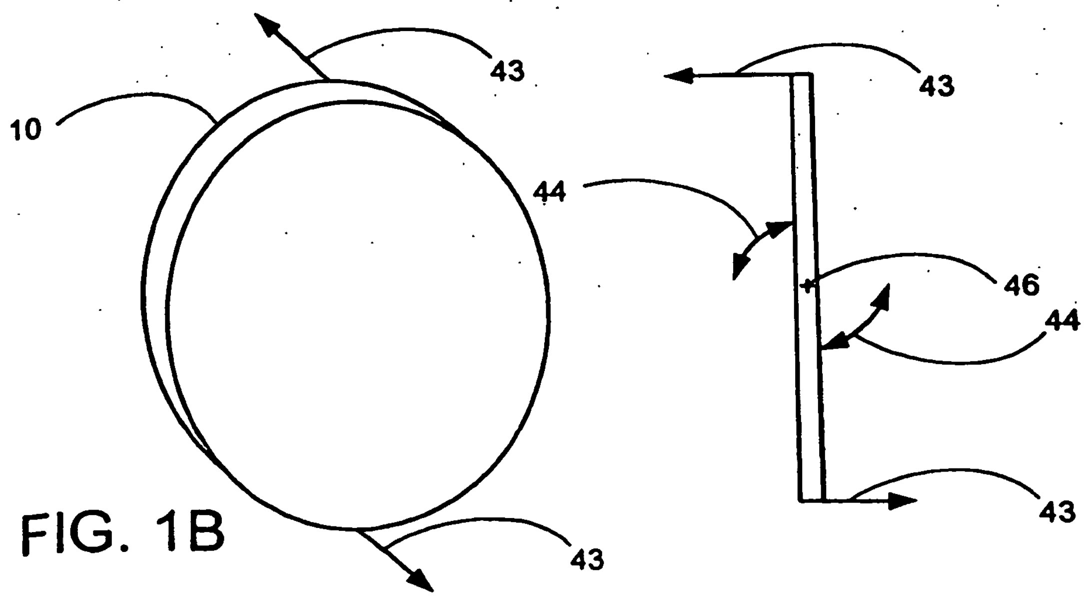

FIG. 1B

FIG. 2A

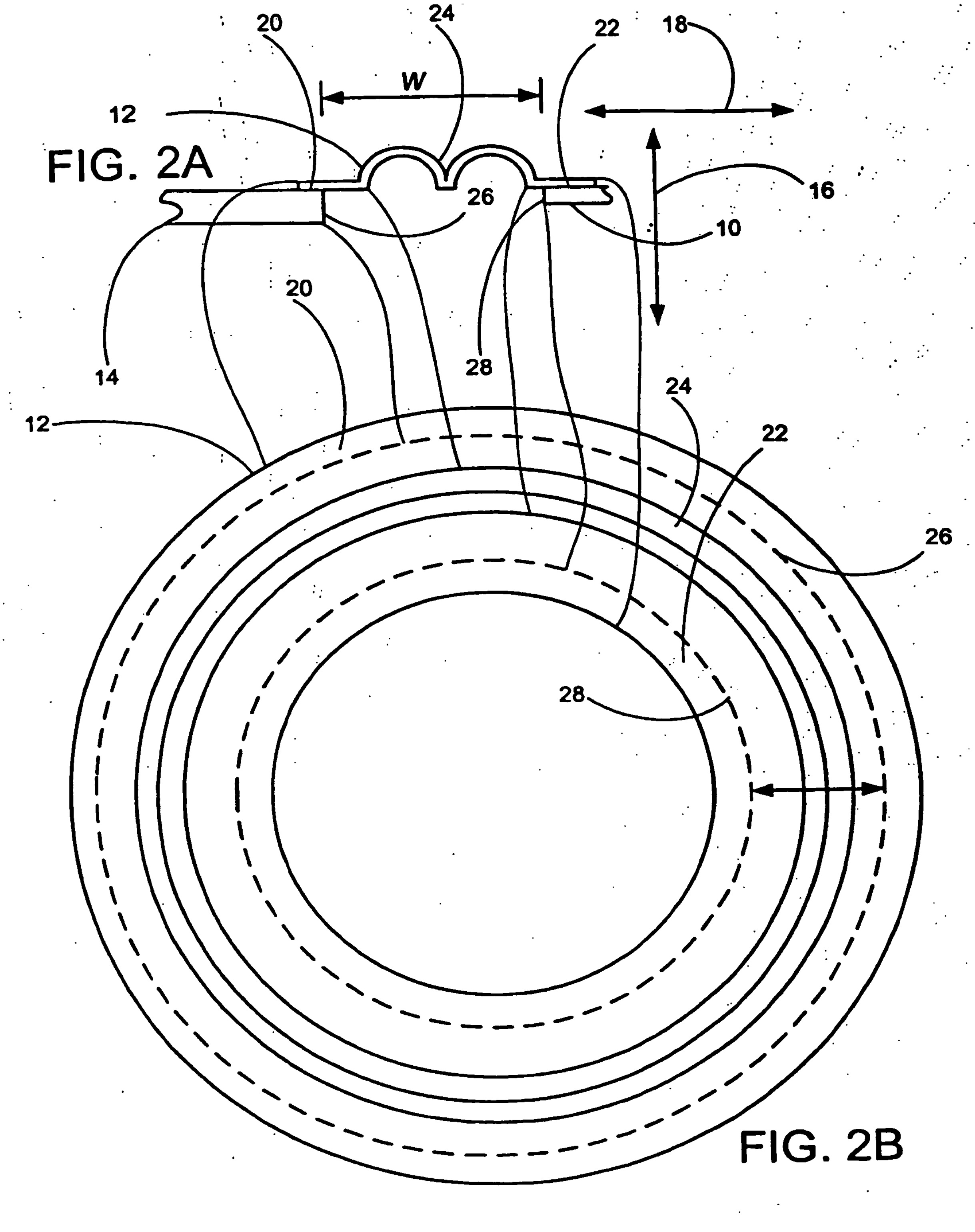

FIG. 2B

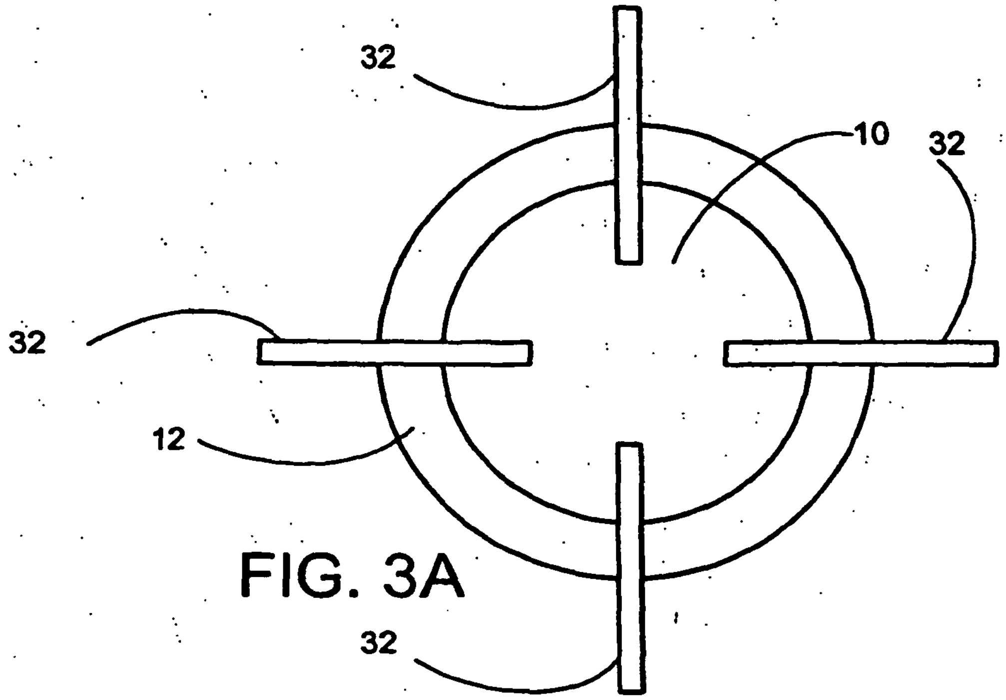

FIG. 3A

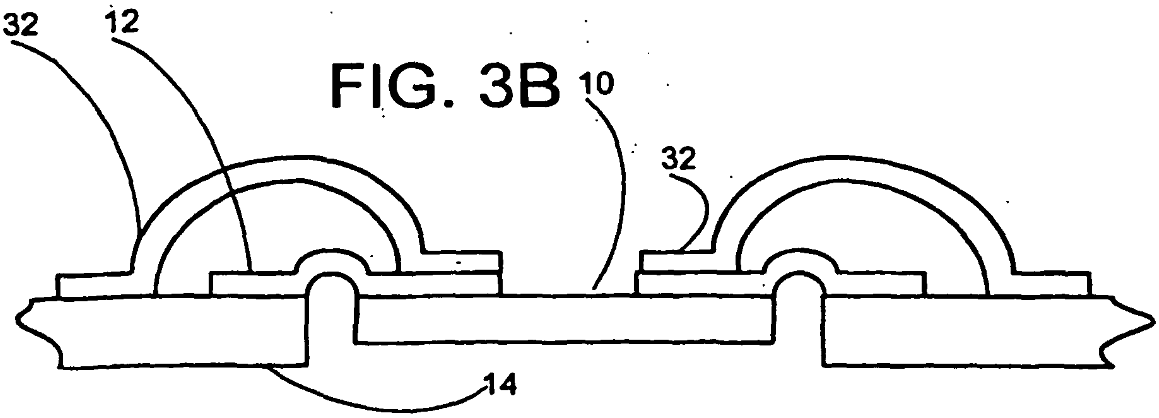

FIG. 3B

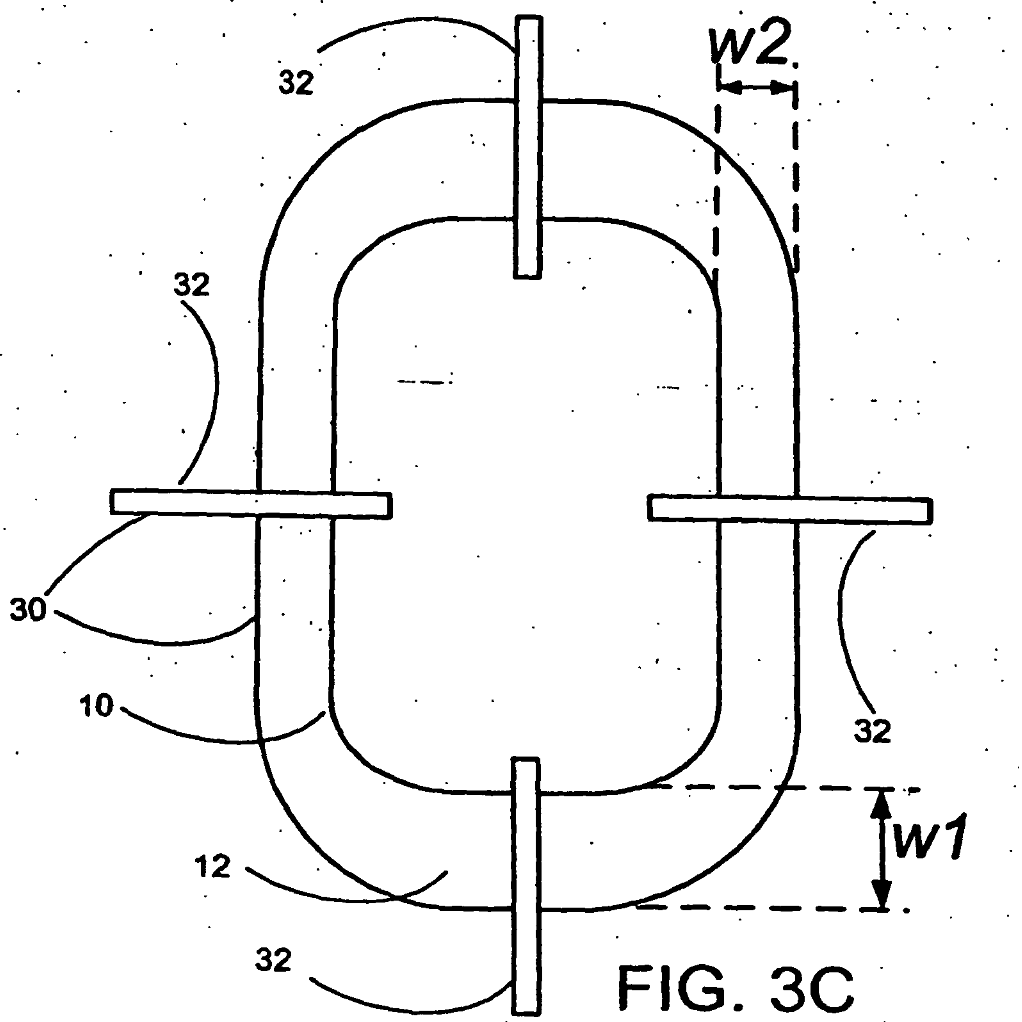

FIG. 3C

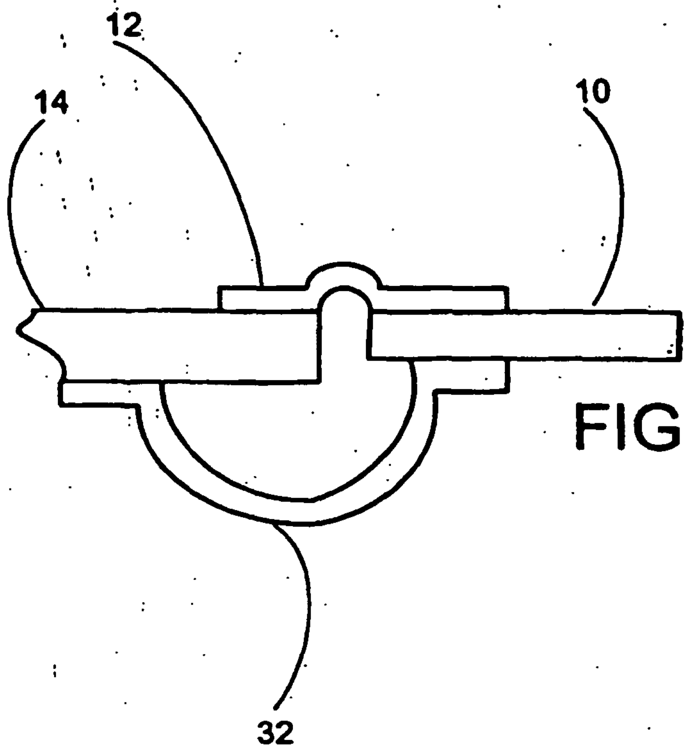

FIG. 3D

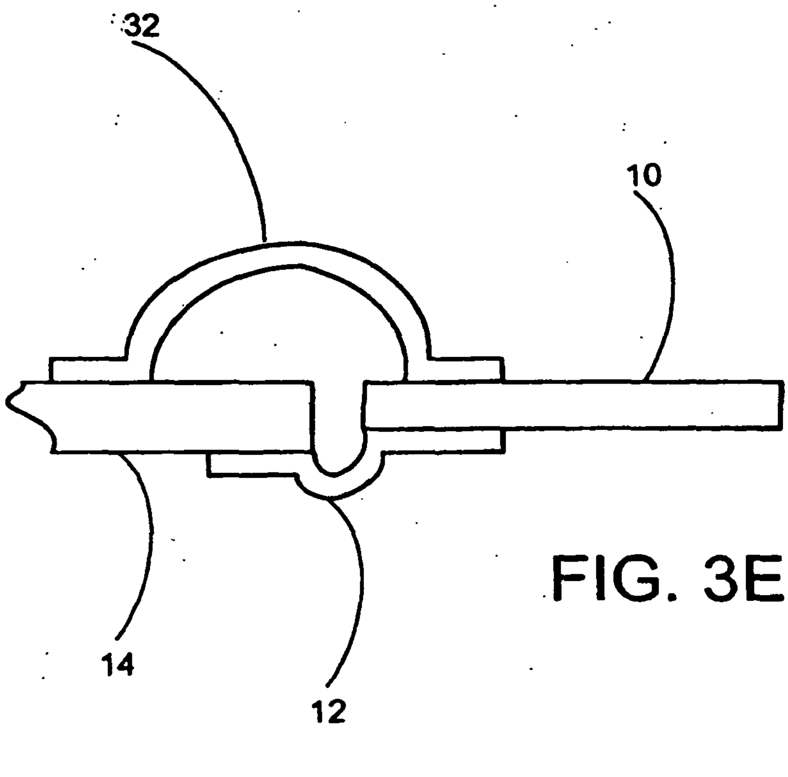

FIG. 3E

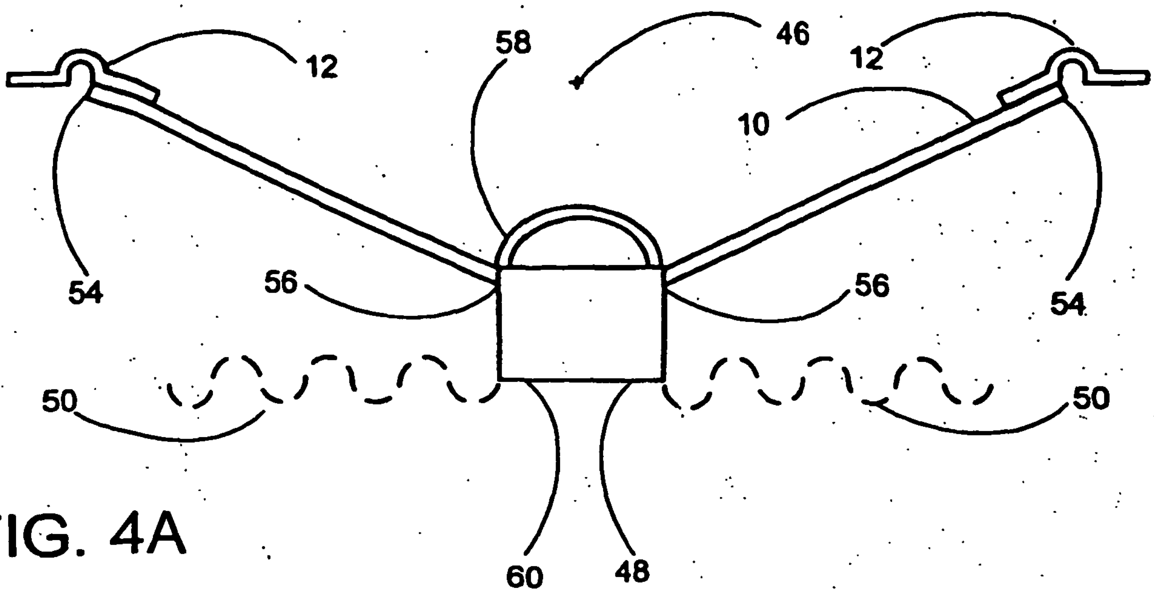

FIG. 4A

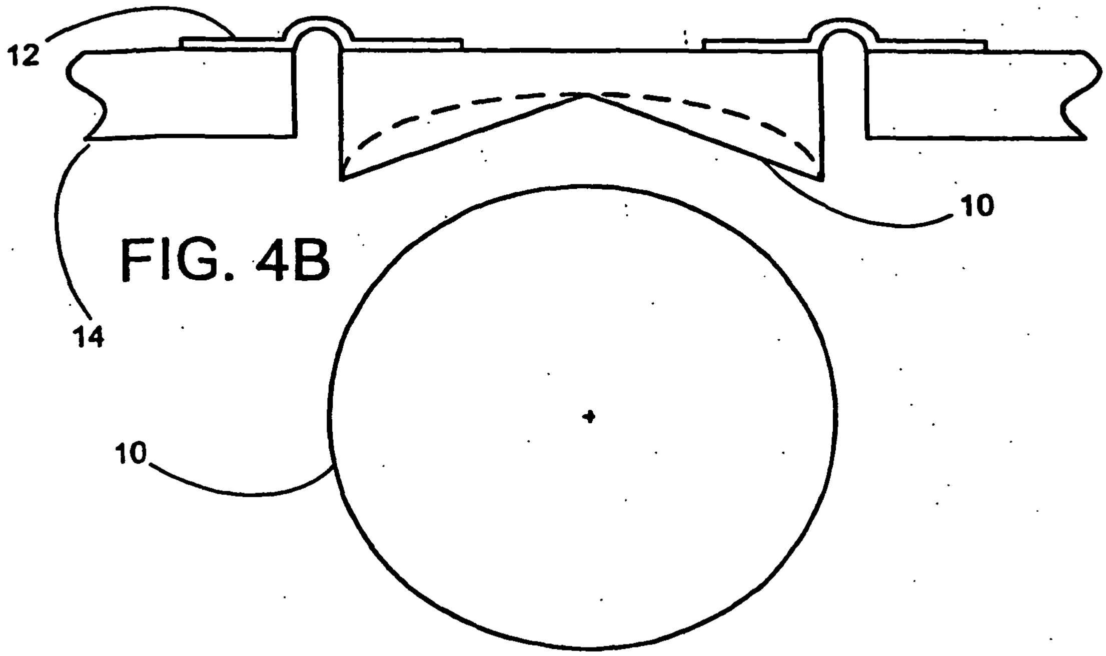

FIG. 4B

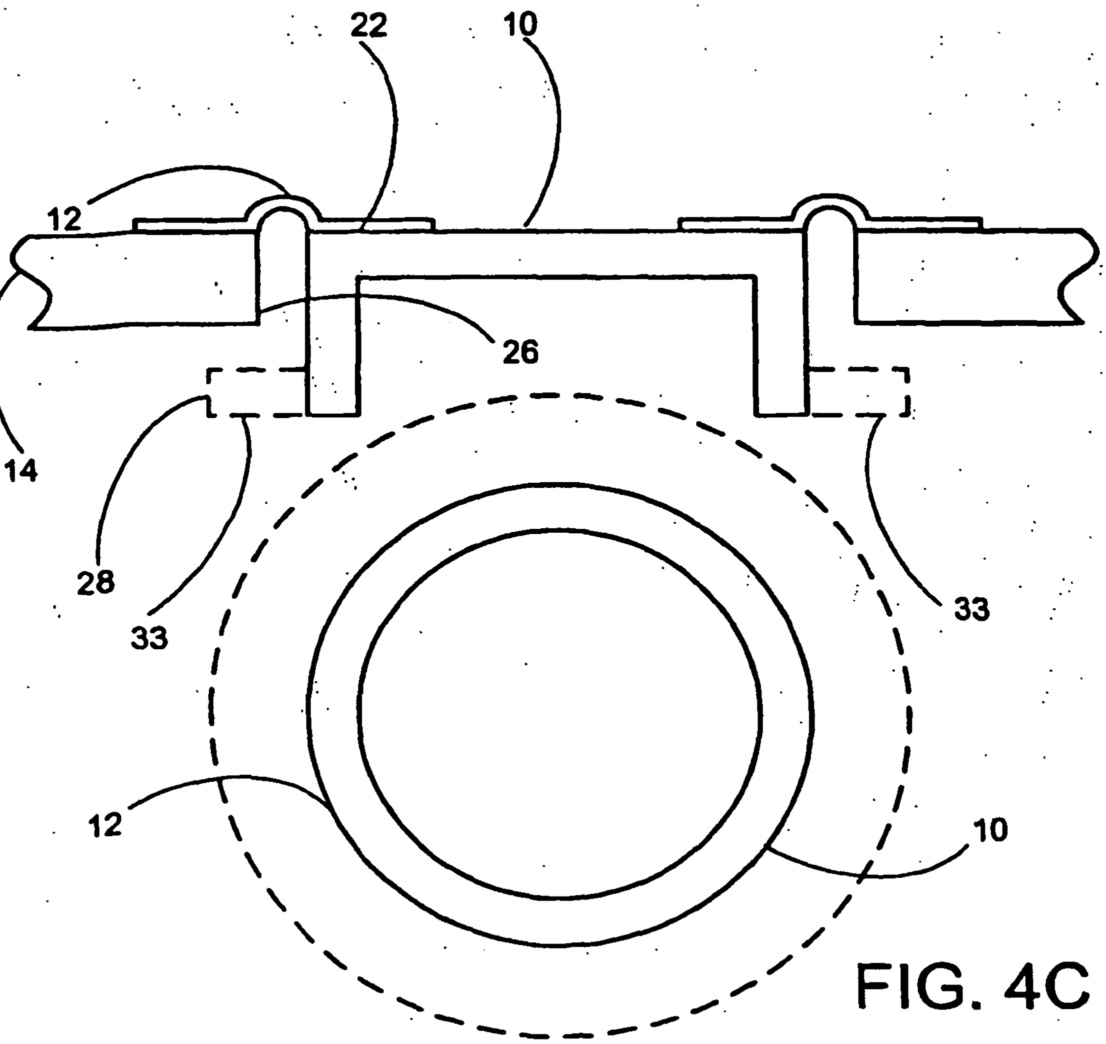

FIG. 4C

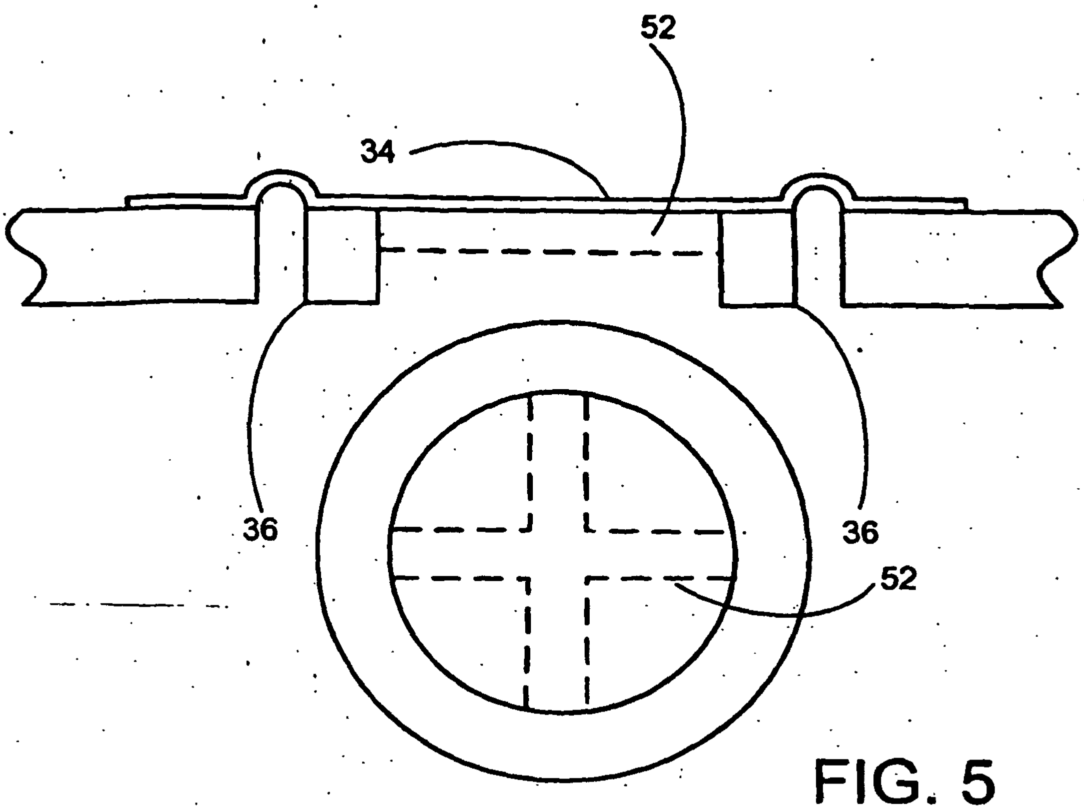

FIG. 5

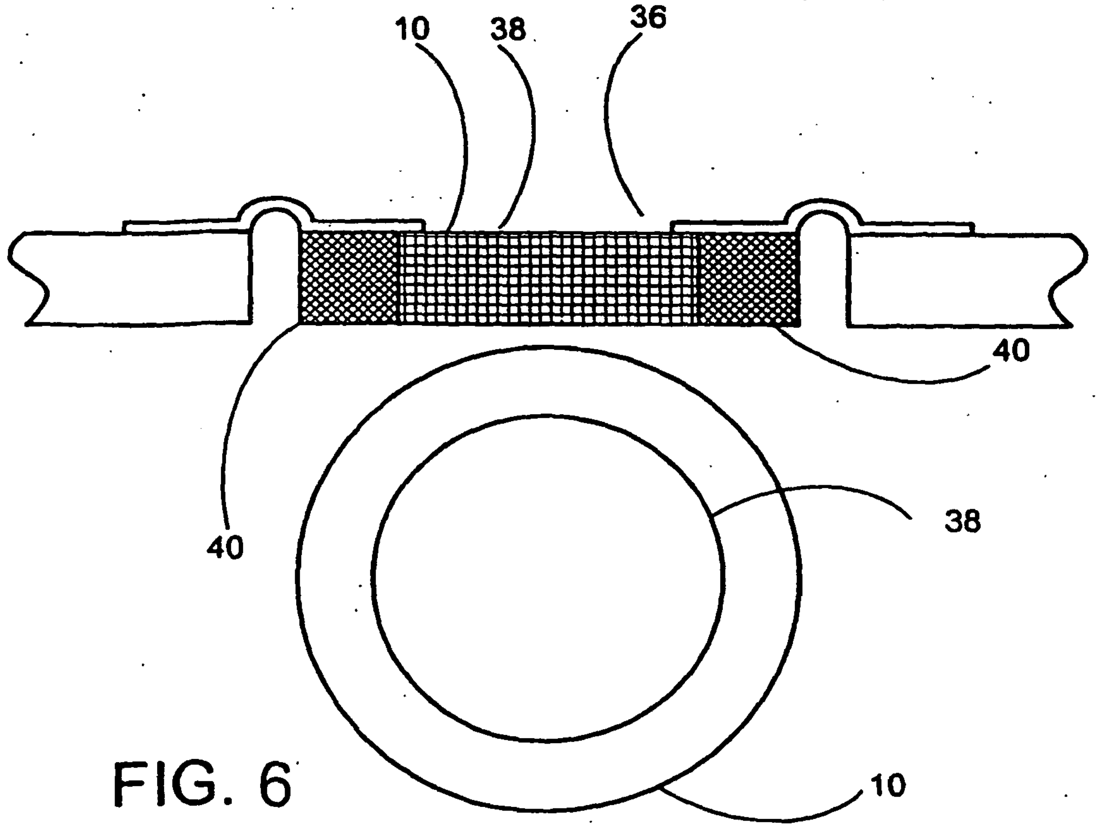

FIG. 6

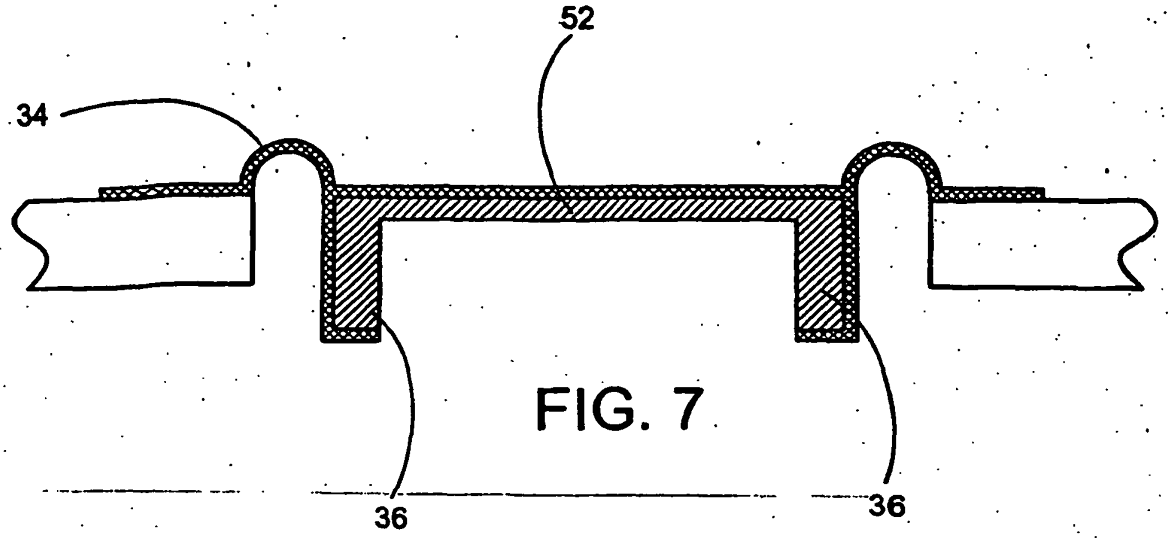

FIG. 7

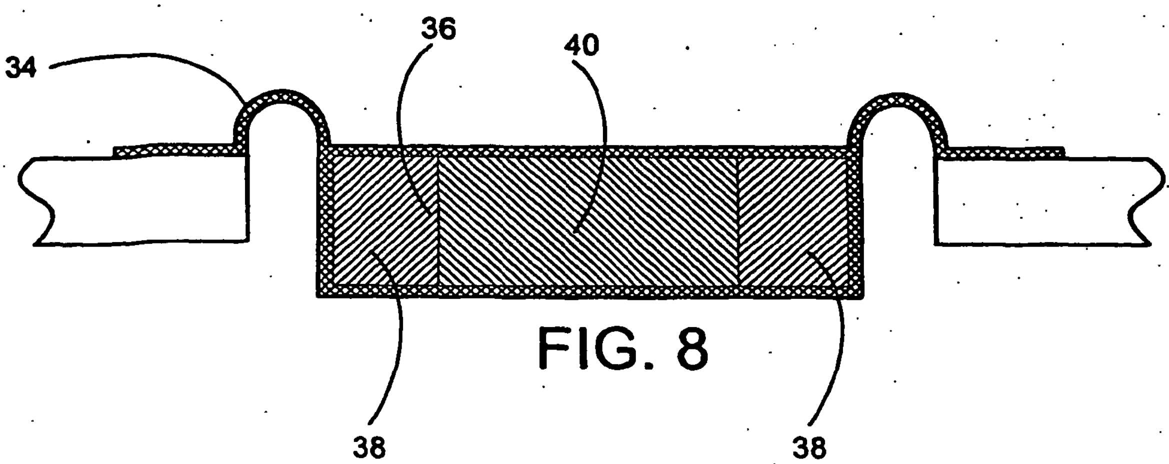

FIG. 8

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- US 3780824 A **[0002]**